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DEVELOPMENT OF A COMPUTER GRAPHIC METHODOLOGY FOR INVESTIGATING--ETC(U)
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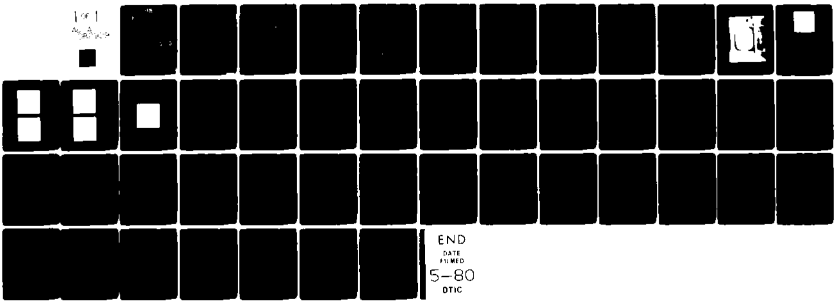

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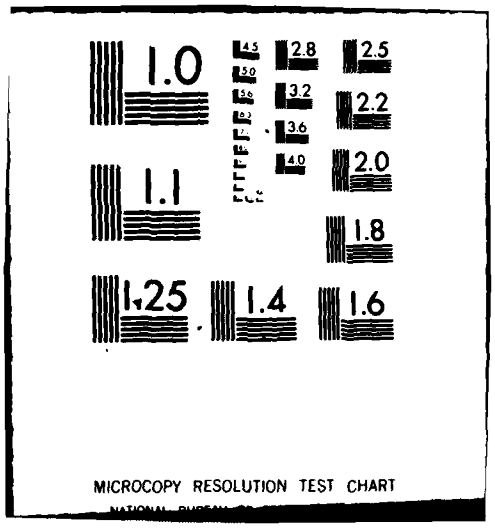
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Technical Note 2-80

DEVELOPMENT OF A COMPUTER GRAPHIC METHODOLOGY FOR INVESTIGATING THE DECISION MAKING ASPECTS OF SUPPRESSION

Chauncey E. Wilson
James P. Torre, Jr.

January 1980
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A graphic computer simulation was developed for a pilot experiment designed to examine decision making in a no-risk situation. This experiment was a precursor of a detailed investigation of suppression. Male and female soldiers viewed a CRT display showing a series of minefield patterns of varying density. In Phase I, they estimated the probability that a tank image could pass through the minefield patterns. In Phase II, they decided whether or not to send the tank image across the minefields. Subjects'

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estimates of probabilities of success in Phase I closely matched the actual probabilities of success. However, the proportion of "go" decisions made in Phase II did not parallel subjects' estimates of probabilities of mission success. Female subjects took more time to make decisions in Phase II than males, but there were no differences in predictive ability between males and females. A methodology to examine the effect of risk on decision making is discussed and additional studies are recommended.

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DEVELOPMENT OF A COMPUTER GRAPHIC METHODOLOGY FOR INVESTIGATING THE DECISION MAKING ASPECTS OF SUPPRESSION

Chauncey E. Wilson
James P. Torre, Jr.

Professional Assistance

Mr. Richard Camden
Ms. Linda Fatkin
Mr. Dominick J. Giordano
Dr. Gerald Hudgens

Technical Assistance

Mr. Samuel T. Brainerd

January 1980

APPROVED: John D. Weisz
JOHN D. WEISZ
Director
U.S. Army Human Engineering Laboratory

U.S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland 21005

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DEVELOPMENT OF A COMPUTER GRAPHIC METHODOLOGY FOR INVESTIGATING THE DECISION MAKING ASPECTS OF SUPPRESSION

INTRODUCTION

Background

The phenomenon of fire suppression (reduced combat capability under threat) is an important concern of military strategists. To understand suppression, investigators must answer several questions. What extrinsic factors, such as pay and disciplinary procedure, and intrinsic factors, such as self-esteem, need for achievement, and feelings of personal control, motivate soldiers? What is the relationship between actual risk (i.e., the magnitude of objective threat) and the soldiers' perceptions of risk? How does being a member of a military group affect an individual's perceptions of, and reactions to, combat threat situations? Although social psychologists have examined motivation (1,2), risk taking (3,4), and group influences on individual behavior (5,6), a great deal of their research has used college students in academic settings as subjects. Since the military population differs from the student population in many ways, only tenuous generalizations about soldiers' behaviors in military situations can be made from research on college students.

Recent field studies (7,8) have provided a limited amount of information about suppression; however, a comprehensive study of the psychology of suppression requires the development of new experimental techniques. The Army Scientific Advisory Panel Ad Hoc Group on Fire Suppression (9) has suggested that suppression can be examined through the use of a computer-driven tactical simulation. In an extension of the Ad Hoc Group's suggestion, we propose that a tactical computer simulation, used in conjunction with a system for allocating rewards and punishments and determining levels of intrinsic motivation, could be a useful method for examining the functional relationships among objective threat, perceived threat, and tactical decision making. Possible refinements of this methodology and suggestions for future research are covered in detail in the discussion section of this report.

This study, a computer simulation, represents the first step in the development of a new method for examining suppression. A preliminary version of a tactical computer simulation was developed and used to assess the accuracy of subjects' perceptions of objective threat and to determine the relationship between these perceptions and subsequent tactical decisions. In this developmental study, there were no tangible consequences associated with decision making.

Overview

Male and female soldiers and male marines were asked to participate in a pilot study of perceptual accuracy and decision making. Phase I of the experiment consisted of a test which required subjects to estimate the probability that a video image of a tank on a CRT screen could move across a pattern of points representing mines without touching any of them. Tank images that touched the points were considered destroyed. A different pattern of points was used for each trial. During Phase II of the experiment, subjects were presented with a second series of minefield patterns and told to send the tank image across the minefield only if they felt that it would cross the pattern without being destroyed. In Phase II, subjects received scores which reflected the success of their decision. Subjects' scores on individual trials and their cumulative scores were registered at the bottom of the CRT screen.

OBJECTIVES

The objectives of this experiment were:

1. To determine the usefulness of a preliminary version of a computer graphic simulation for studying decision making.

2. To assess subjects' ability to make judgments about the likelihood of success of simulated tactical events.

3. To determine the relationship between subjects' probabilistic judgments and subsequent decisions when these decisions had no consequences.

METHOD

Subjects

The subjects were 11 male marines from the 2nd Marine Division, Camp LeJeune, North Carolina; 7 male soldiers from the 82nd Airborne Division, Fort Bragg, North Carolina; and 18 female soldiers from Company D, 12th OSUT Battalion Training Brigade, Fort McClellan, Alabama. The 36 subjects used in this study were drawn from a larger sample of participants engaged in the Human Engineering Laboratory Load Bearing System Test (10). All subjects were volunteers. Table 1 provides a summary of the subjects' demographic characteristics.

TABLE 1

Characteristics of Experimental Sample

	Male Marines Range	Male Marines Mean	Male Soldiers Range	Male Soldiers Mean	Female Soldiers Range	Female Soldiers Mean
Age (years)	18-21	19.7	19-21	19.6	18-23	19.4
Length of Service (months)	12-28	22.6	13-29	18.7	3-7	3.9
MOS	0311		11B		95B	
(Frequency)	11		7		18	
Rank	E1 E2	E3 E4	E1 E2	E3 E4	E1 E2	E3 E4
(Frequency)	0 4	6 1	0 0	5 2	11 4	1 1

Experimenters

One male and one female served as experimenters in this study. Each experimenter tested an equal number of male and female subjects. In order to standardize the manner in which subjects received instructions from the two experimenters, a script (Appendix A) was prepared.

Apparatus

Two subsystems of the Human Engineering Laboratory Command/Control Simulator Facility were used for this study: the IDIIOM (CRT) display and the Varian F/100 computer. The display is shown in Figure 1.

Computer Program

Two versions of a program called "MINE" were used to generate visual information on a CRT display. Both versions generated a series of 100 different patterns of small points of light (mines) enclosed within a 10- x 10-inch square on the display. The program presented subjects with a tank image that moved in a straight line from a random point at the lower edge of the CRT screen to the upper edge of the screen. The area that enclosed the mines was scaled to represent a 200- by 200-meter square. The tank was scaled to represent the top view of an M60 tank (Figure 2).

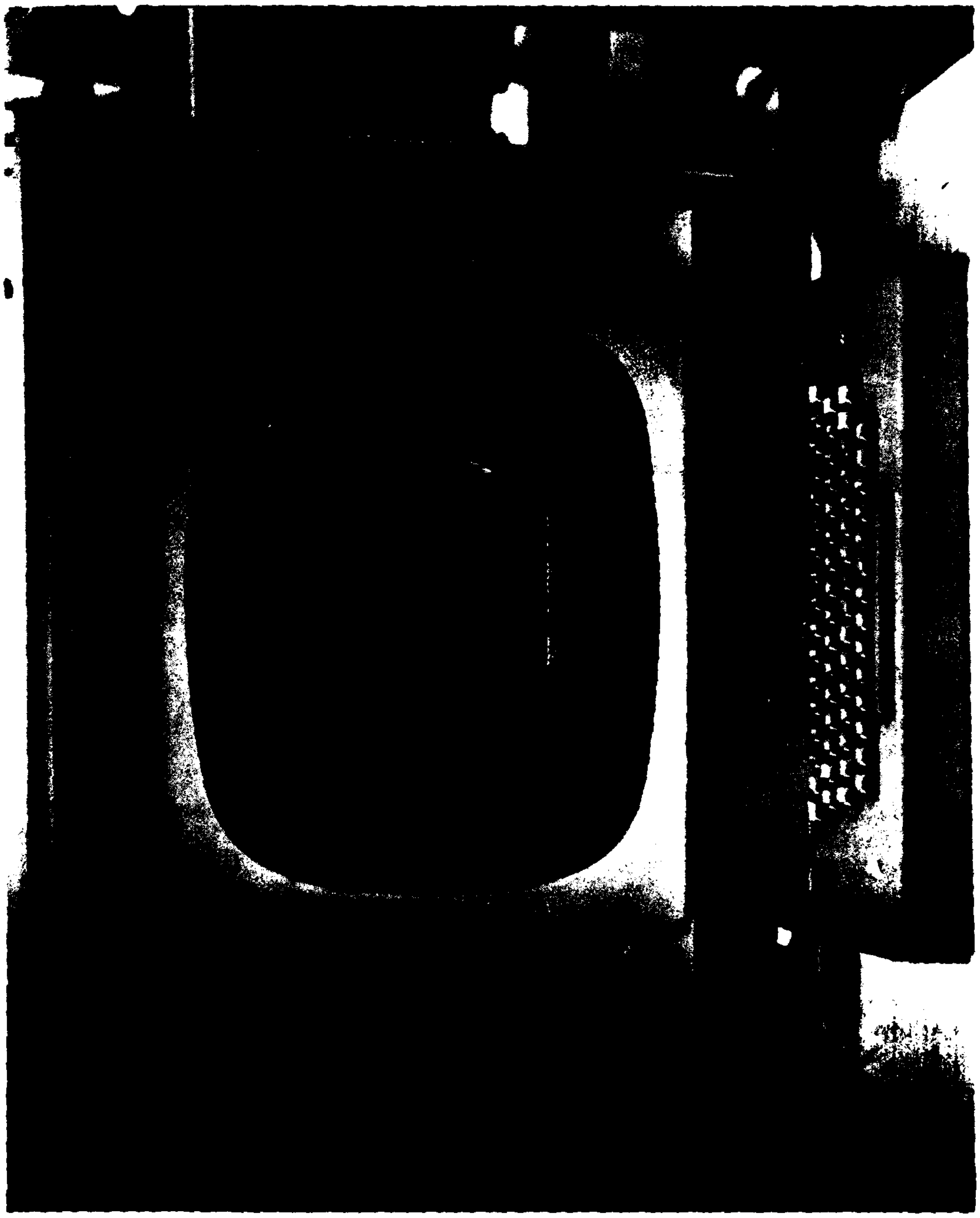


Figure 1. CRT display and control apparatus.

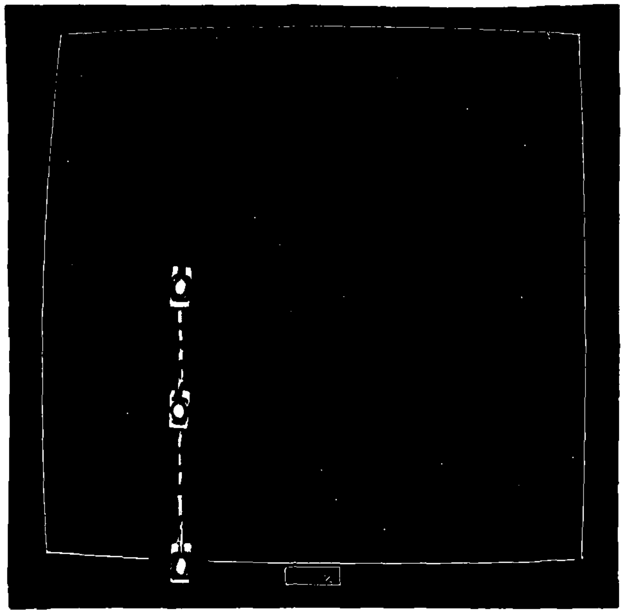


Figure 2. Tank videoimage.

One hundred different minefield patterns were presented in random order to each subject. The series of patterns consisted of twenty different arrangements of points (or mines) for each of five minefield densities.

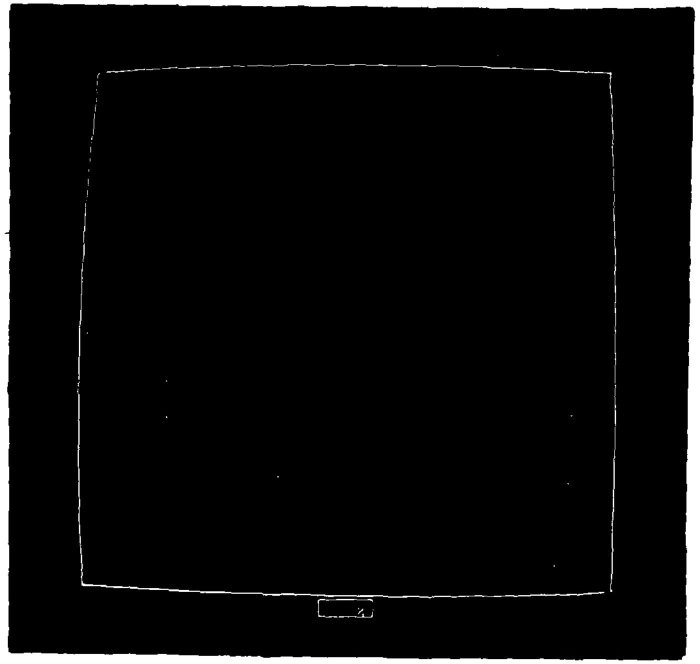
The five densities were chosen by a Monte Carlo technique such that the probabilities of a successful target crossing were 0.90, 0.70, 0.50, 0.30, and 0.10. These patterns were generated with the constraint that mines would not all be found in a small area of the CRT screen. Figure 3 illustrates the various densities of mines presented to the subjects.

PROCEDURE

Phase I: Probabilistic Judgment Test

An experimenter seated each subject in front of the CRT display and read the standard set of instructions. First the general procedure for the experiment was described and then the experimenter outlined the specific procedure for Phase I. The subjects were told that 100 different patterns of mines would be presented on the CRT and that they would have to estimate the probability that a simulated tank could move across the patterns without touching any of the mines (See Figure 3).

The subject's estimate for each experimental trial was recorded by pressing numbered keys on a computer terminal. The estimate for each trial was displayed at the bottom edge of the CRT screen. After making an estimate, subjects pushed a "go" key and the target would appear at a random point along the bottom line on the screen and travel vertically



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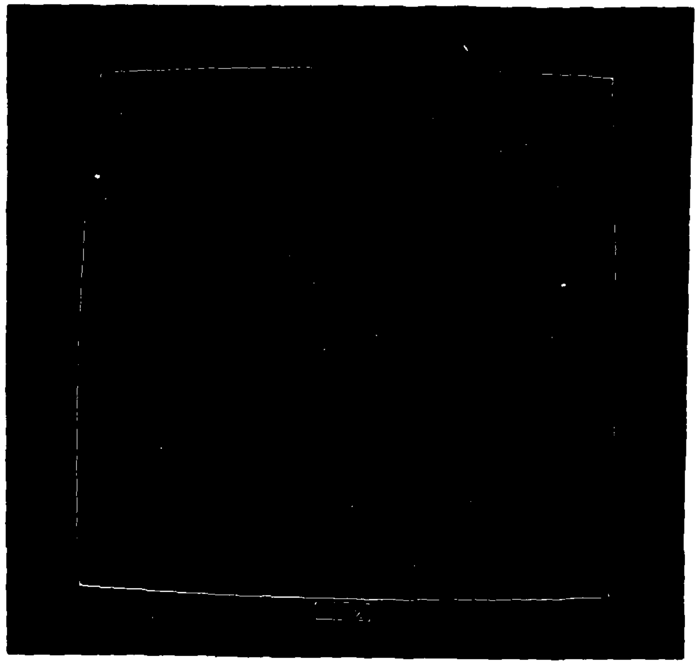

3b

Actual Probability of Success = .90

Number of Mines = 5

Simulated Density = 1.20×10^{-4} mines per square meter

Actual Probability of Success = .70

Number of Mines = 17

Simulated Density = 4.0×10^{-4} mines per square meter

Figure 3. Description of visual stimuli.

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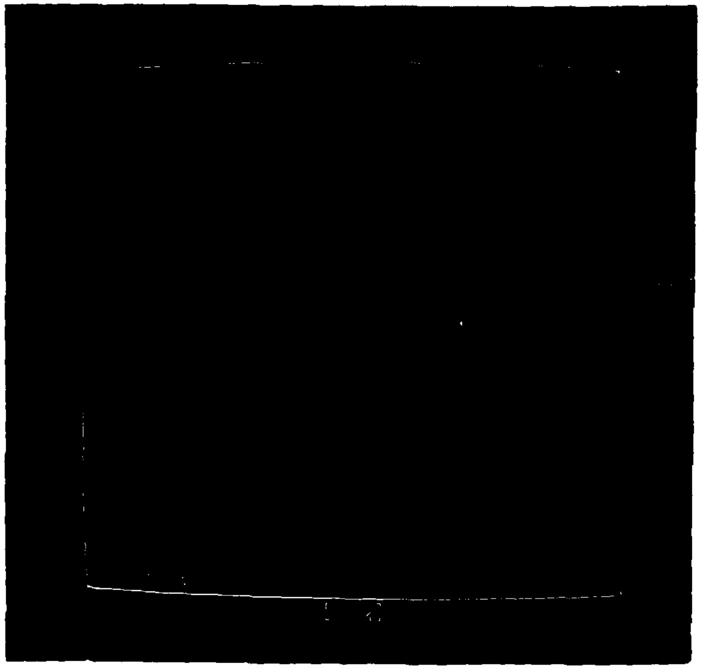

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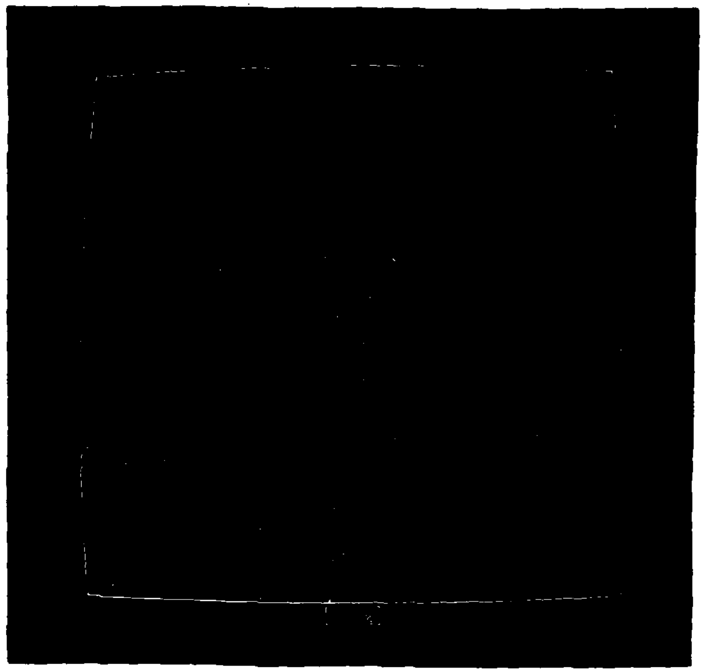

3d

Actual Probability of Success = .50

Number of Mines = 34

Simulated Density = 8.50×10^{-4} mines per square meter

Actual Probability of Success = .70

Number of Mines = 58

Simulated Density = 1.45×10^{-3} mines per square meter

Figure 3. Description of visual stimuli.

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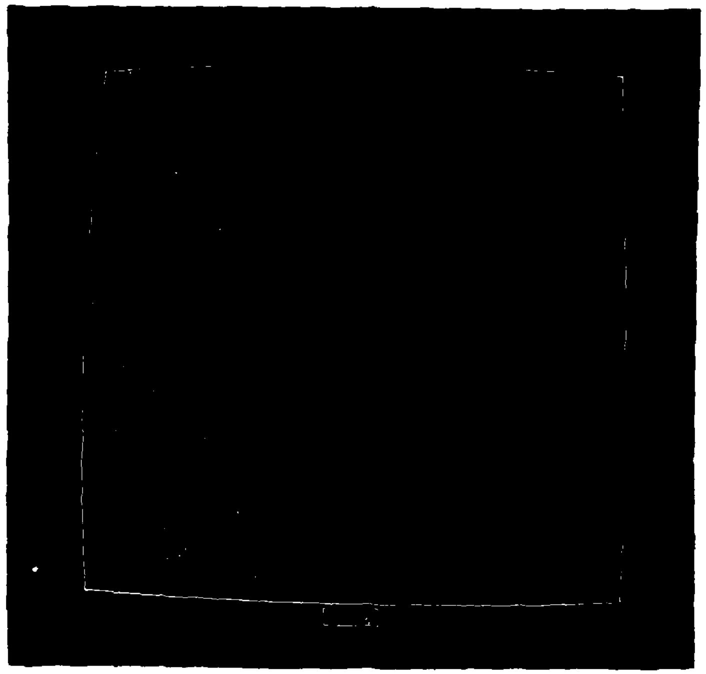

3e

Actual Probability of Success = .10

Number of Mines = 112

Simulated Density = 2.80×10^{-3} mines per square meter

Figure 3. Description of visual stimuli.

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across the pattern. If the target crossed the pattern successfully, the trial ended and a new pattern of points was displayed. If the target made contact with a point, there was a small flash on the screen (to represent an explosion) and a new pattern was displayed.

After the instructions were read, subjects were given five practice trials and asked if they had any final questions about the procedure. Any subject who was still unsure of the procedure was given additional practice trials.

Phase II: Decision Making Test

Approximately three hours after Phase I, each subject was seated in front of the CRT and Phase II commenced. In this phase, they were required to decide whether or not to send the tank image across the screen rather than to make abstract probability estimations. Subjects were once again presented with a series of 100 trials. The series of trials was the same as that given in Phase I, but the order of presentation was reversed. Subjects were instructed to push a "go" key if they felt that the tank would cross the screen successfully. After either key was pushed, the tank appeared and began to travel vertically across the pattern. Subjects received a score on each trial which reflected the success of their decision making. The scoring criteria were:

a. 5 points earned if the subject pushed the go key and the tank made a successful crossing.

b. 5 points deducted if the subject pushed the go key and the tank did not make a successful crossing.

c. 1 point earned if the subject pushed the no-go key when the tank would have been destroyed.

d. 3 points deducted if the subject pushed the no-go key when the tank would have make a successful crossing.

The extreme scores, +5 and -5 were chosen arbitrarily to represent total mission success and total mission failure, respectively. The intermediate scores, +1 and -3, were chosen to represent the hypothetical utility of subjects' decisions. An implication of this scoring system is that attempting to complete a mission is somewhat more important than preserving one's equipment (i.e., tank) for future missions.

After the experimenter had described the scoring system, subjects were told that the maximum possible score on the decision making test was 300 points. The trial numbers, the scores for each trial, and the subjects' cumulative scores were displayed at the bottom of the CRT screen. Subjects were not given information about other participants' scores.

Subjects were given five practice trials after the procedure was described. Those still unsure of the procedure were given additional practice.

Debriefing

After they completed the experiment, the subjects were told about the specific objectives of this pilot experiment and of possible future tests and were shown their performance data from Phase I and Phase II. Subjects were asked if they had any questions about the research. With the exception of questions asked about other subjects' performance, all questions were answered by the experimenters. Before leaving the Command/Control Computer Facility, subjects were asked not to reveal their scores or decision making techniques to other subjects until the entire experiment was completed.

Experimental Design

The experimental design for this study is shown in Table 2. Each experimenter tested an equal number of male and female subjects, but the assignment of subjects could not be random because the number of male and female subjects varied from day to day.

Two sequences of minefield patterns were viewed by subjects. Sequence B was the reverse of Sequence A. In Phase I, half of the subjects viewed Sequence A and half viewed Sequence B. In Phase II, each half viewed the other sequence.

RESULTS

Phase I Results

Comparison of Probability Estimates

The distribution of subjects' estimates of the probabilities of success for the five densities of minefields are shown in Figures 4 through 8. The distributions, as one might expect, are skewed left or right depending on the proximity to a 0 or a 1 actual probability of success. Characteristics of each estimation distribution are found in Table 3.

TABLE 2

Experimental Design

Subject #	Sex of Subject	Sex of Experimenter	Phase I Sequence	Phase II Sequence
1	M	M	A	B
2	M	M	B	A
3	M	F	A	B
4	M	F	B	A
5	F	M	A	B
6	M	M	B	A
7	M	F	A	B
8	M	F	B	A
9	M	M	A	B
10	M	M	B	A
11	M	F	A	B
12	F	M	B	A
13	F	M	A	B
14	F	M	B	A
15	F	M	A	B
16	F	M	B	A
17	F	F	A	B
18	F	F	B	A
19	F	F	A	B
20	F	F	B	A
21	F	M	A	B
22	F	M	B	A
23	F	M	A	B
24	F	F	B	A
25	F	F	A	B
26	F	F	B	A
27	F	M	A	B
28	F	F	B	A
29	M	M	A	B
30	M	M	B	A
31	M	F	A	B
32	M	F	B	A
33	M	F	A	B
34	M	M	B	A
35	M	M	A	B
36	M	F	B	A

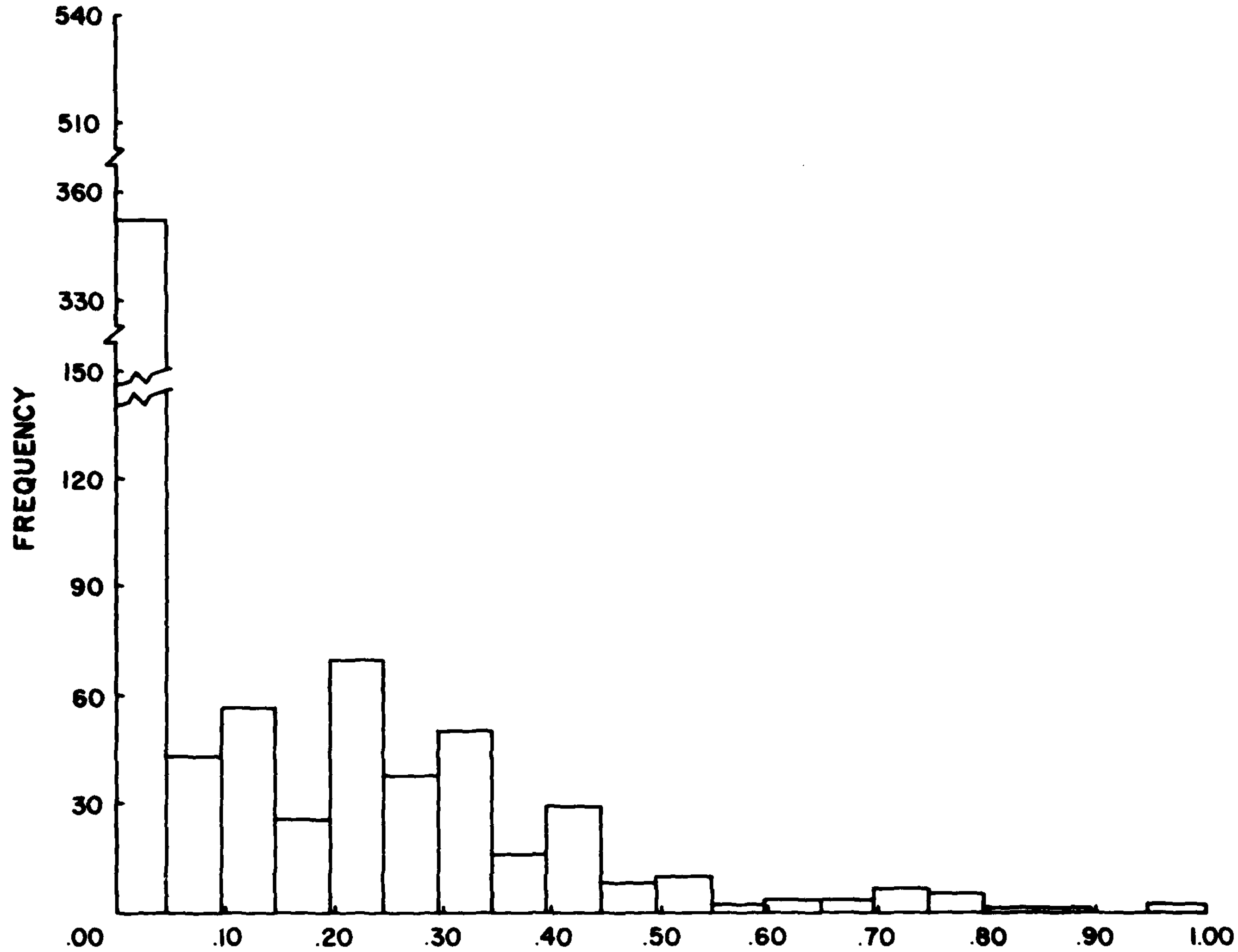

Figure 4. Frequency of estimates of perceived probability of success: Actual probability of success = .10.

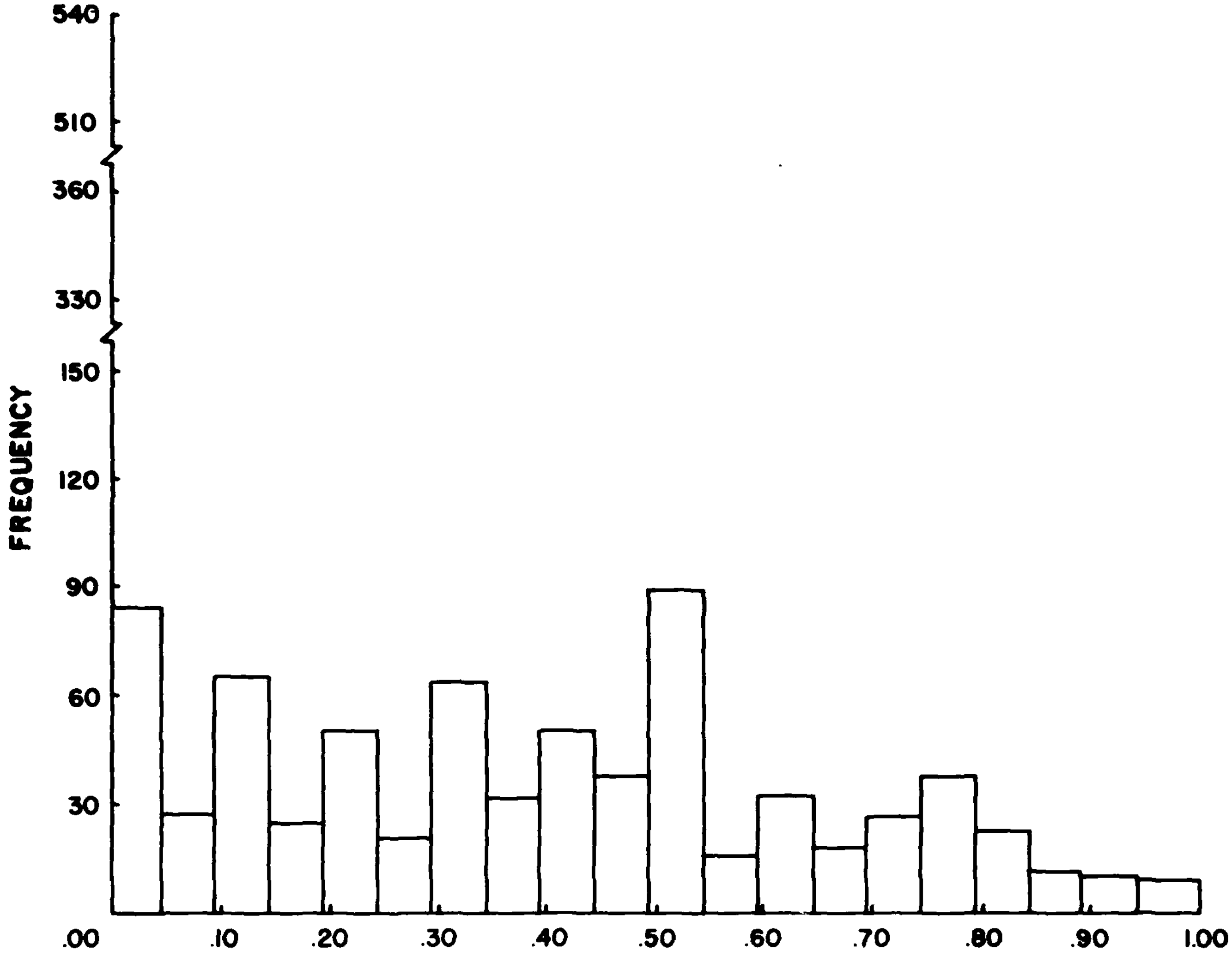

Figure 5. Frequency of estimates of perceived probability of success: Actual probability of success = .30.

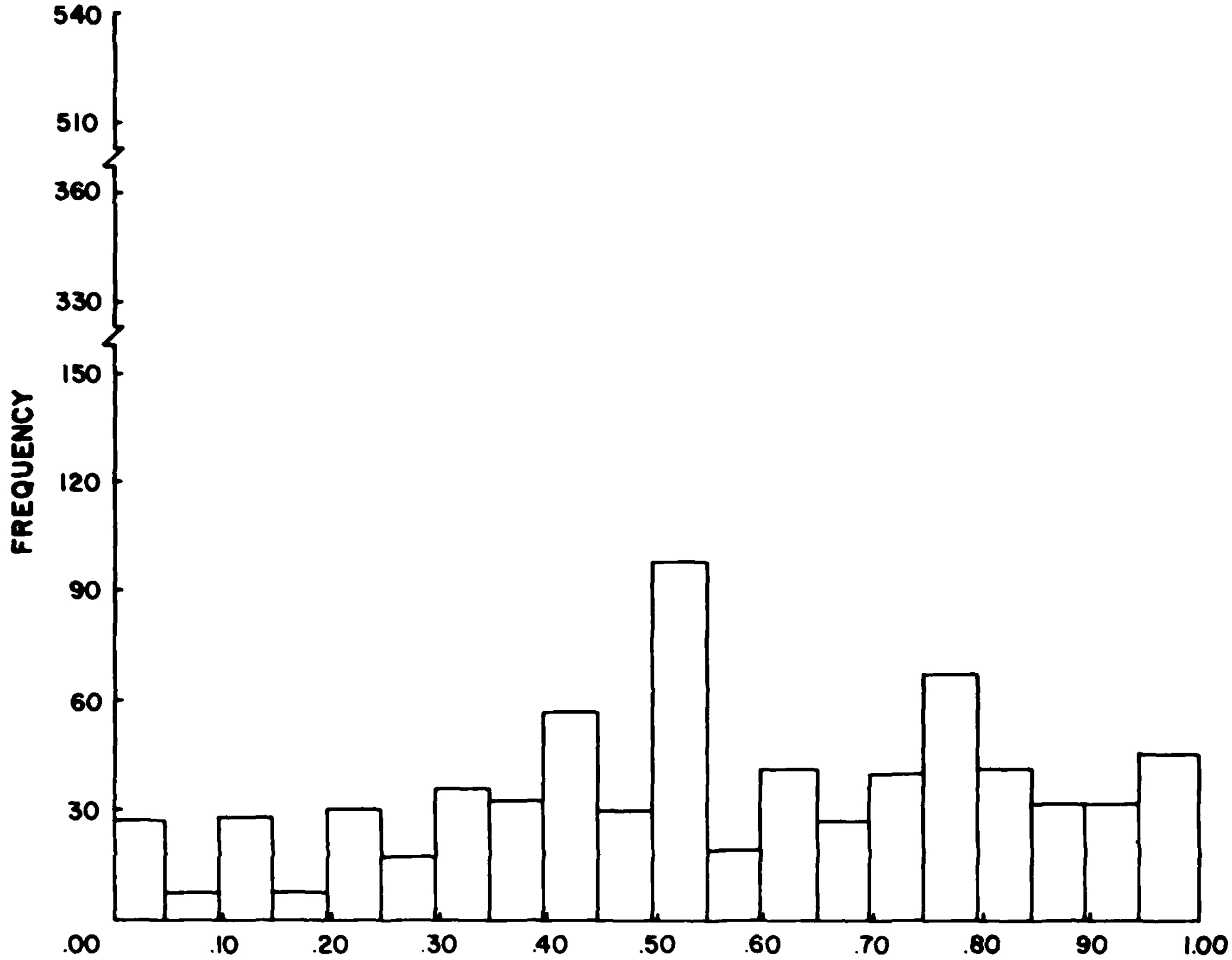

Figure 6. Frequency of estimates of perceived probability of success: Actual probability of success = .50.

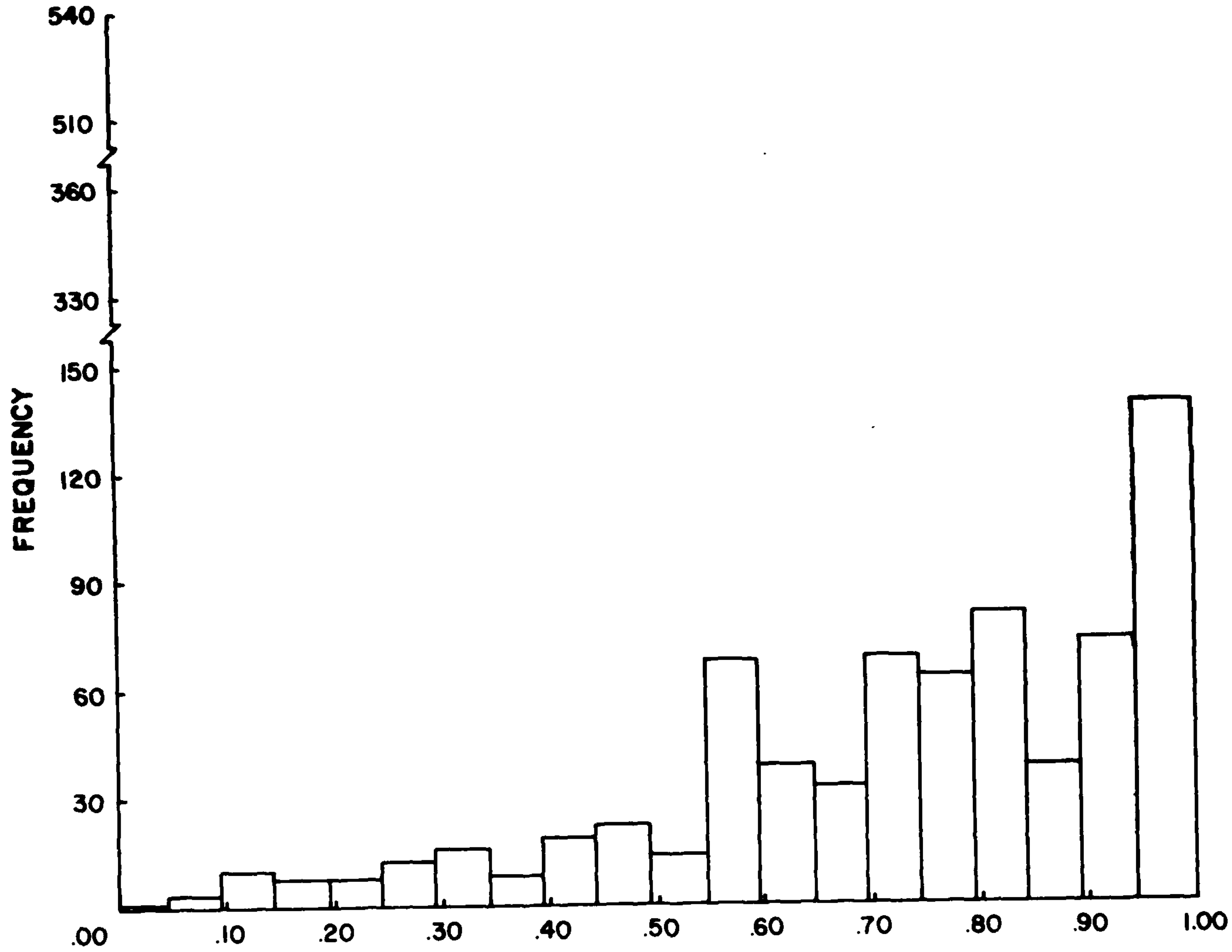

Figure 7. Frequency of estimates of perceived probability of success: Actual probability of success = .70.

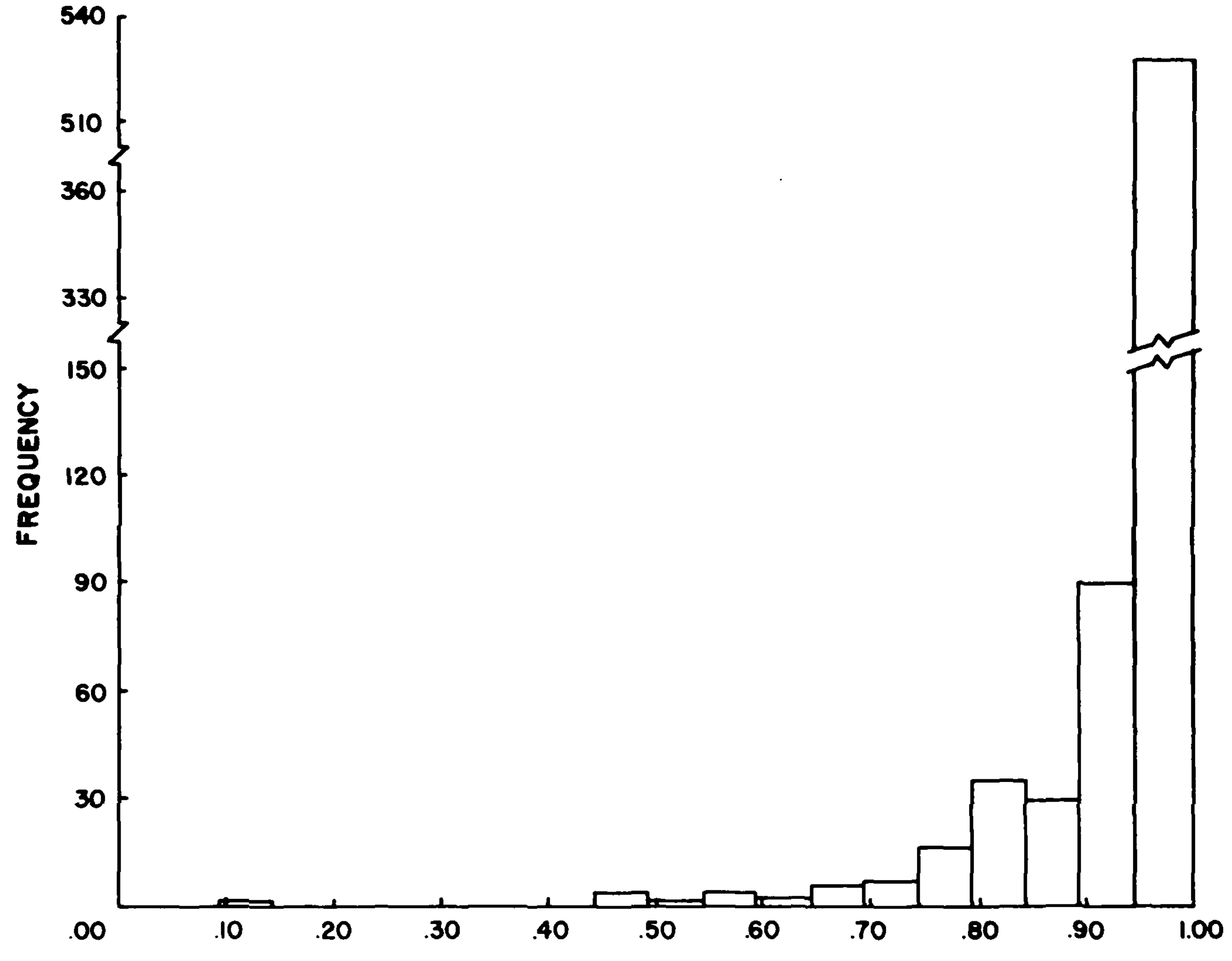

Figure 8. Frequency of estimates of perceived probability of success: Actual probability of success = .90.

TABLE 3

Characteristics of Phase I Estimation Distributions

Actual Probability of Success	.10	.30	.50	.70	.90
Mean of Subjects' Estimates	.13	.36	.54	.71	.94
Standard Deviation of Subjects' Estimates	.13	.20	.21	.19	.07
Median Value of Subjects' Estimates	.06	.39	.64	.77	.96

Individual subject's mean estimates of the probability of a successful target crossing for each of the five actual probabilities of success are presented in Table 4. Each of the subject means is based on twenty trials of a constant density. Examination of Table 4 reveals that overestimation of probability of success is most frequent for the .90 category. There is a slight tendency toward overestimation in the .30, .50, and .70 categories.

Means and standard deviations of subjects' probability estimates for each of the minefield densities are found in Table 5. The table shows mean probability estimates by the sex of the subject. The means are plotted on Figure 9 as a function of minefield density. The small offset among the curves in Figure 9 indicates that subjects' mean estimates of probabilities of success are close to the actual probabilities.

A visual examination of Figure 9 shows that male subjects tended to overestimate the probability of success more than females. The differences between male and female estimates tend to increase with decreasing actual probability of success. However, a multivariate profile analysis (11) indicates that the judgments of males and females are parallel and are not significantly different (T^2 & $t<1$, p=n.s.).

The only difference between actual and predicted probabilities of success for all subjects that is statistically significant ($t=2.93$, $p<.05$) occurs for a .9 actual probability of success. However, because of the highly skewed nature of the estimation distribution, this difference may be illusory (see Figure 8).

Time Required to Make Probabilistic Judgments

Table 6 lists the total amount of time that it took individual subjects to make a series of 100 probability estimations. Decision time means and standard deviations are shown by sex of subject and sex of experimenter in Table 7. Subjects' mean decision times are similar for male and female experimenters, but female subjects appear to take less time to decide than male subjects. However, a 2x2 Anova on the decision times revealed no statistically significant differences for sex of experimenter or sex of subject. There was no significant correlation between total decision time and estimation accuracy.

Phase II Results

Decision Making Test Scores

During Phase II, subjects received scores that reflected the success of their decisions whether or not to send the target across the simulated minefields. Table 8 indicates how frequently each score was obtained. Subjects made correct decisions (scored +1 or +5) in 71% of the trials.

TABLE 4

Subjects' Mean Estimates (N=20) of the Probability of a Successful Tank Crossing

Subject Number	Actual Probability of Success				
	.90	.70	.50	.30	.10
	Mean Estimated Probability of Success				
1	.78	.56	.50	.43	.30
2	.99	.75	.68	.46	.19
3	1.00	.89	.69	.57	.24
4	.84	.54	.33	.13	.01
5	.99	.86	.65	.45	.10
6	.93	.71	.45	.27	.05
7	.99	.75	.47	.28	.04
8	.99	.77	.68	.61	.30
9	.94	.63	.42	.21	.03
10	.99	.96	.90	.46	.24
11	1.00	.95	.84	.81	.35
12	1.00	.93	.76	.32	.06
13	.95	.81	.65	.56	.34
14	1.00	.97	.81	.35	.08
15	.98	.85	.70	.50	.04
16	.93	.65	.42	.21	.08
17	.91	.72	.55	.45	.05
18	.93	.47	.13	.03	.00

(Continued)

TABLE 4 (Continued)

Subjects' Mean Estimates (N=20) of the Probability of a Successful Tank Crossing

Subject Number	Actual Probability of Success				
	.90	.70	.50	.30	.10
19	.98	.67	.60	.35	.00
20	.83	.18	.06	.00	.00
21	.99	.85	.67	.64	.28
22	1.00	.73	.54	.30	.00
23	1.00	.73	.54	.30	.00
24	.99	.94	.76	.66	.36
25	.68	.38	.31	.19	.03
26	.92	.51	.29	.12	.01
27	.87	.72	.47	.31	.00
28	.95	.48	.20	.09	.00
29	.95	.42	.32	.23	.04
30	.97	.71	.43	.21	.00
31	.97	.73	.66	.51	.18
32	.98	.92	.80	.62	.32
33	.97	.73	.61	.47	.26
34	.98	.81	.64	.48	.22
35	.99	.55	.23	.07	.00
36	.82	.54	.37	.29	.13

(Concluded)

TABLE 5

Actual and Estimated Probability of a Successful Tank Crossing

Actual Probability of Success	Density of Minefield ("mines"/m^2)		Mean Estimated Probability of Successful Target Crossing		
			Male	Female	Combined
.90	1.20×10^{-4}	Mean	0.949	0.937	0.943
		S.D.	0.066	0.080	0.072
		N	18	18	36
.70	4.00×10^{-4}	Mean	0.718	0.698	0.708
		S.D.	0.155	0.217	0.186
		N	18	18	36
.50	8.50×10^{-4}	Mean	0.557	0.517	0.537
		S.D.	0.193	0.233	0.211
		N	18	18	36
.30	1.45×10^{-3}	Mean	0.395	0.344	0.364
		S.D.	0.195	0.211	0.202
		N	18	18	36
.10	2.80×10^{-3}	Mean	0.161	0.091	0.129
		S.D.	0.129	0.130	0.129
		N	18	18	36

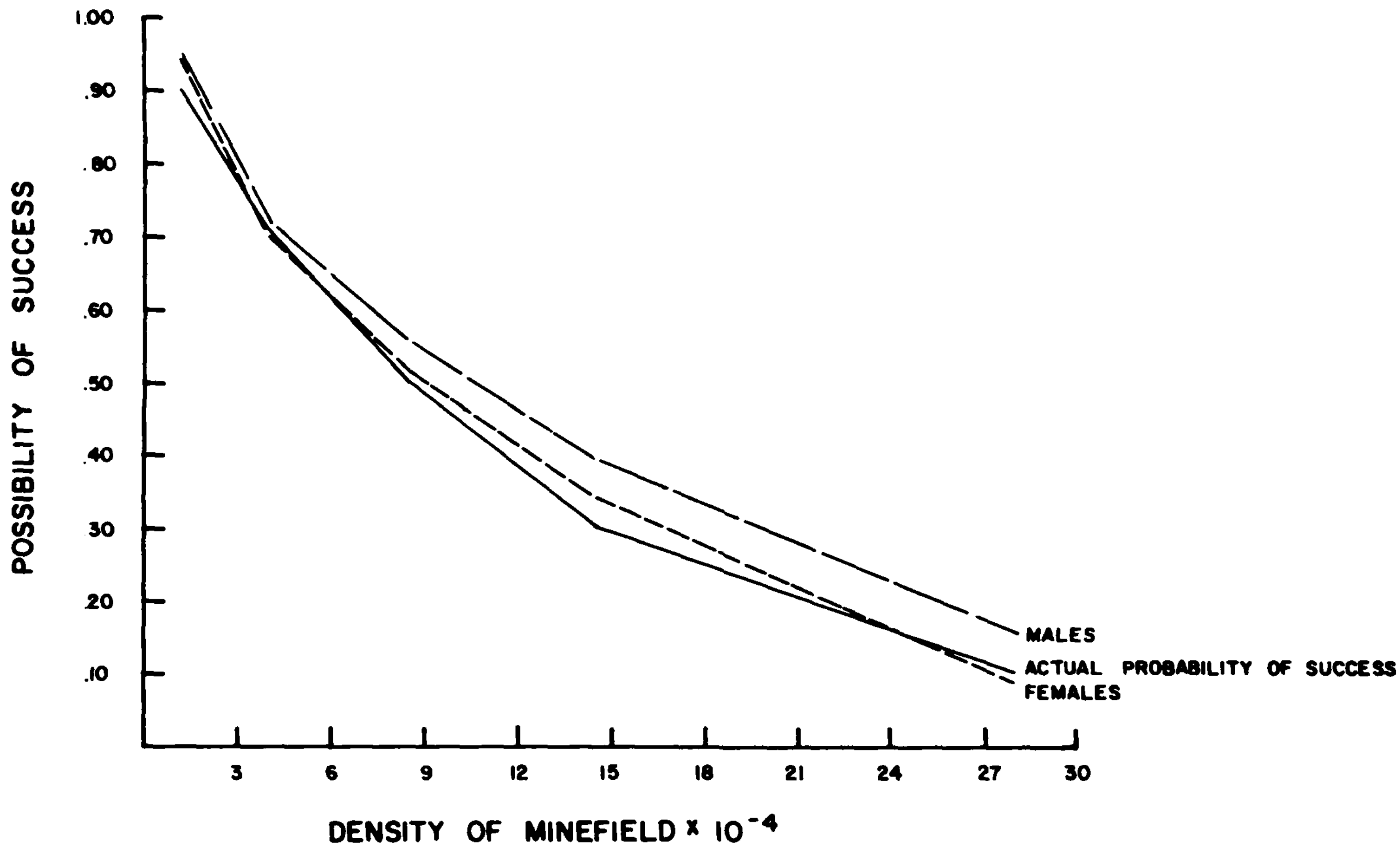

Figure 9. Mean estimated probability of success versus minefield density.

TABLE 6

Total Phase I Decision Time

Subject #	Total Phase I Decision Time (Secs.)
1	175.4
2	175.7
3	287.9
4	184.3
5	193.7
6	222.6
7	310.7
8	112.2
9	188.5
10	169.2
11	241.3
12	277.5
13	123.9
14	506.1
15	218.8
16	498.0
17	93.5
18	178.8
19	193.4
20	195.7
21	115.9
22	465.1
23	198.1
24	167.3
25	459.4
26	197.0
27	195.4
28	188.9
29	220.2
30	164.4
31	184.6
32	106.1
33	201.7
34	218.7
35	302.3
36	195.7

TABLE 7

Mean Phase I Decision Time

		Sex of Subject	
		Male	Female
Sex of Experimenter	Male	Mean = 637.3 S.D. = 233.4	Mean = 572.4 S.D. = 245.6
	Female	Mean = 696.3 S.D. = 240.8	Mean = 573.2 S.D. = 159.0

TABLE 8

Distribution of Phase II Scores

Score Value	-5	-3	+1	+5
Proportion of Decisions	.199	.091	.290	.420
Number of Decisions	716	329	1043	1512

Individual trial scores were summed to form an overall decision making score (Table 9). A breakdown of mean overall decision making scores and standard deviations by sex of subject and sex of experimenter is presented in Table 10. The differences are quite small. A 2x2 Anova showed that neither the sex of the subject nor the sex of the experimenter had a statistically significant effect on decision making scores.

TABLE 9

Overall Decision Making Score By Sex of Experimenter and Sex of Subject

MALE EXPERIMENTER				FEMALE EXPERIMENTER			
MALE SUBJECTS		FEMALE SUBJECTS		MALE SUBJECTS		FEMALE SUBJECTS	
Subject #	Score	Subject #	Score	Subject #	Score	Subject #	Score
1	114	5	122	3	124	16	112
2	144	12	120	4	96	17	144
6	136	13	78	7	150	18	130
9	116	14	146	8	104	19	106
10	126	13	120	11	92	20	124
29	66	21	78	31	100	24	58
30	132	22	92	32	130	23	114
34	96	23	162	33	132	26	106
35	116	27	84	36	120	28	138

TABLE 10

Mean Decision Making Scores

		Sex of Experimenter		
		Male	Female	Combined
Sex of Subject	Male	116.20	116.44	116.33
	Female	111.33	114.67	113.00
	Combined	113.78	115.56	114.67

Relationship Between Phase I Probability Estimation and Phase II Decisions

In this experiment, we wanted to determine the correspondence between Phase I abstract judgments and Phase II tactical decisions. Two different approaches were used to determine the relationships between subjects' Phase I estimates and Phase II decisions.

First, we correlated subjects' total decision making scores with a measure of subjects' probability estimation accuracy. This measure of estimation accuracy was derived by computing the absolute deviations between actual probabilities of success and subjects' mean estimates of the probability of success for each minefield density. In order to form a global "error" score (Table 11), we summed the deviations across densities and determined the mean absolute deviation of the five densities for each subject. Subsequently, we correlated the error scores with the subject's overall decision making scores.

Prior to the experiment, we predicted a negative correlation between error scores and decision making scores; that is, subjects who were poor at making probability estimates, and thus had large error scores, were expected to have lower decision making scores. A regression analysis indicated a moderate degree of support for this hypothesis ($r = -.456$, $P < .01$).

In the second approach, we compared group estimates of the probability of mission success for each minefield density with the proportion of "go" decisions made in Phase II. The relationships among the means of subjects' estimates of probabilities of success, the actual probabilities of success, and their Phase II go decisions are found in Table 12, and are portrayed graphically in Figure 10. Subjects' willingness to initiate simulated tactical missions was not linearly related to subjects' perceptions of risk from Phase I. For the two lowest categories of probability of success, .10 and .30, the proportions of go responses were less than the means of subjects' probability estimates. For the three highest categories,

TABLE 11

Phase I Error Scores and Phase II Decision Making Scores

Subject #	Error Score*	Decision Making Score	Subject #	Error Score*	Decision Making Score
1	11.8	114	19	7.2	106
2	11.4	144	20	28.6	124
3	17.8	124	21	18.6	78
4	13.0	96	22	20.6	92
5	11.0	122	23	5.4	162
6	3.4	136	24	22.6	58
7	5.0	155	25	18.2	114
8	17.0	104	26	13.8	106
9	7.0	116	27	3.8	84
10	21.0	126	28	17.6	138
11	29.0	92	29	12.8	66
12	13.0	120	30	6.8	132
13	16.2	78	31	11.0	100
14	15.0	146	32	22.8	130
15	13.8	120	33	10.8	132
16	5.4	112	34	12.6	96
17	7.6	144	35	16.8	116
18	20.0	130	36	8.2	120

*The error scores were formed by finding the differences between the subjects mean estimated probability of success and the actual probability of success for each density, summing the absolute values of the differences and dividing this sum by five.

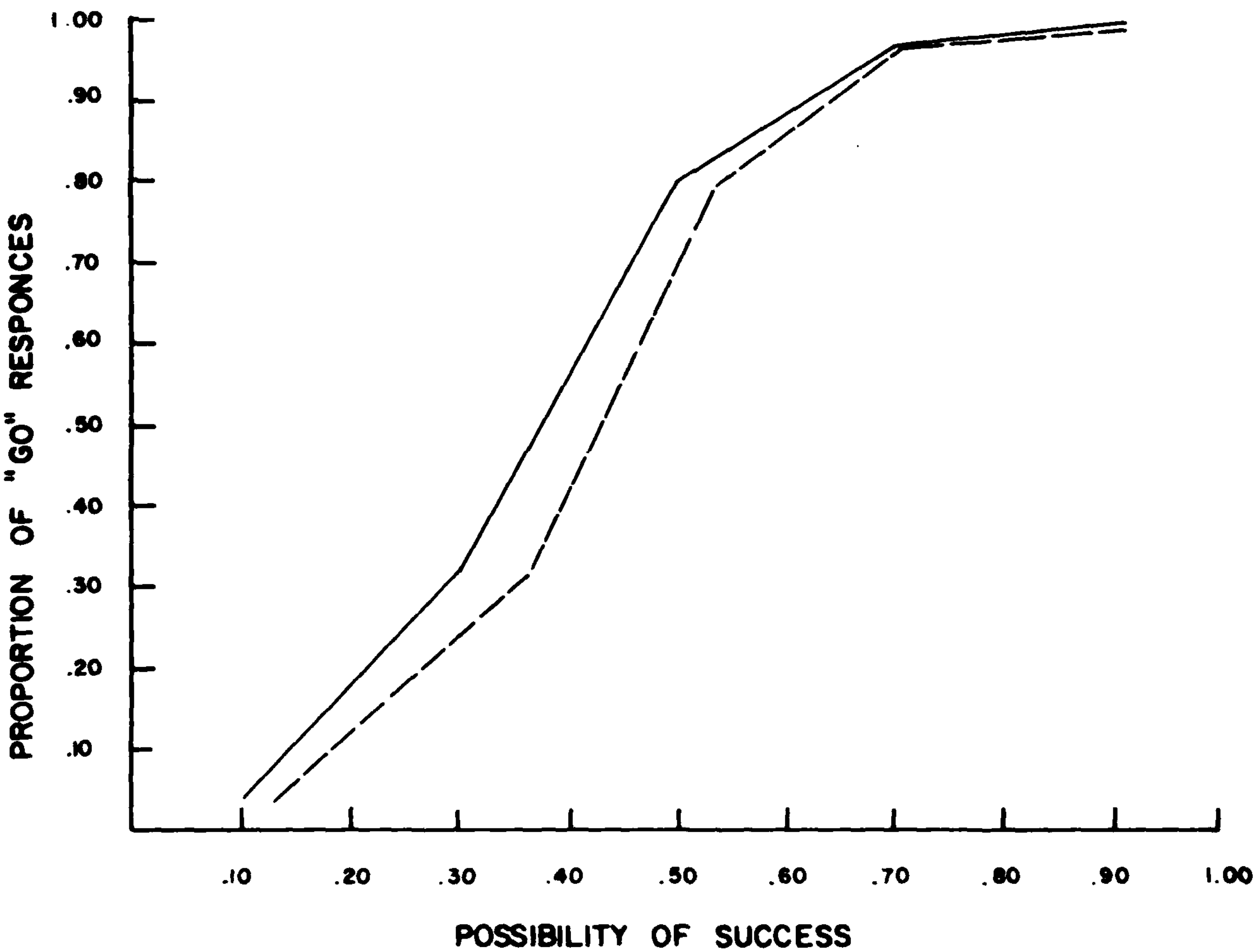

Figure 10. Relationship between Phase I probabilistic judgments and Phase II go decisions.

TABLE 12

Comparison of Phase I Probability Values and Phase II Decisions

Phase I Actual Probability of Success	.100	.300	.500	.700	.900
Phase II Mean of Subjects' Probability Estimates	.129	.364	.537	.708	.943
Phase II Proportion of Go Decisions	.036	.317	.797	.967	.994

.50, .70, and .90, the proportions of go responses were greater than the means of subjects' probability estimates. With the exception of responses to the .30 actual probability of success category, these differences were statistically significant at $p < .01$.

Decision Making Times

Table 13 lists the total Phase II decision time for each subject. There was no significant relationship between total decision time and decision making scores. Data in Table 14 indicate that the decision time increased as the actual probability of success decreased from 0.90 to 0.30. The data also indicate that females tended to take significantly longer to make decisions than males, 3.76 versus 2.56 seconds ($t = 2.10$ $df = 34$, $p < .015$), when the actual probability of success was 0.30. The females' greater deliberation time could be a manifestation of a sex difference in approaches to risk taking situations (12,13), or to a lack of experience with gaming situations. Although females took more time to make decisions than males when the actual probability of success was 0.30, there was no significant difference between the proportion of go responses made by females and the proportion of go responses made by males. T-tests on decision times failed to reveal any sex-of-experimenter effect.

DISCUSSION

General Trend of Results

The experimental group's mean Phase I probability estimates were close to the actual probabilities of success for the five minefield densities. However, there was a high variability in probability estimation among subjects for the intermediate minefield densities and low variability for the two extreme minefield densities. This result was expected since previous research (14,15) has shown that variance in probability estimation is greatest when the actual probability of success is near .5.

TABLE 13

Total Phase II Decision Time

Subject #	Total Phase II Decision Time (Secs.)
1	175.4
2	175.7
3	287.9
4	184.3
5	193.7
6	222.6
7	310.7
8	112.2
9	188.5
10	169.2
11	241.3
12	277.5
13	123.9
14	506.1
15	218.8
16	498.0
17	93.5
18	178.8
19	193.4
20	195.7
21	115.9
22	465.1
23	198.1
24	167.3
25	459.4
26	197.0
27	195.4
28	188.9
29	220.2
30	164.4
31	184.6
32	106.1
33	201.7
34	218.7
35	302.3
36	195.7

TABLE 14

Decision Making By Actual Probability of Success and Sex of Subject

	ACTUAL PROBABILITY OF SUCCESS				
	.90	.70	.50	.30	.10
MALE					
Number	18	18	18	18	18
Mean Decision Time (secs)	1.594	1.844	2.539	2.561	1.667
Standard Deviation	0.520	0.618	0.896	0.873	0.496
FEMALE					
Number	18	18	18	18	18
Mean Decision Time (secs)	1.339	1.928	3.272	3.761	2.106
Standard Deviation	0.463	0.903	2.239	2.295	1.430
COMBINED					
Number	36	36	36	36	36
Mean Decision Time (secs)	1.467	1.886	2.906	3.160	1.886
Standard Deviation	0.502	0.764	1.721	1.816	1.078

Phase II of this experiment allowed us to examine the relationship between subjects' abstract probability estimates and the number of times they would send the tank across the simulated minefields. We found a moderate positive correlation between the accuracy of probability estimation and Phase II mission success. Subjects who made accurate Phase I probabilistic judgments tended to have a higher level of mission success during Phase II than subjects who made poor probabilistic judgments. A graph (see Figure 10) of the subjects; perceptions of probabilities of success for the different minefield densities and the proportion of times that subjects initiated missions shows a non-linear relationship between abstract probability estimation and proportion of initiated computer missions. Subjects initiated more Phase II missions for the two highest density minefields than would be predicted from subjects' mean probability estimates. The curve in Figure 10 was derived from a riskless experimental task. Torre (16) suggests that the shape of the curve will vary as the risks for decision making increase. Data from a future experiment in which subjects' Phase II decisions have consequences could be compared with the data from the current no-risk experiment.

The sex of the experimenter had no significant effect on either Phase I or Phase II dependent measures. The sex of the subject did not effect Phase I probability estimates or Phase II decisions. However, females required significantly more time to make Phase II mission decisions when there was a 0.30 probability of mission success. Since there were no detectable sex-of-experimenter effects, future studies using this method may not require the inclusion of experimenters of opposite sex.

Subject Reactions to the Study

Prior to this study, we believed that some subjects might find the computer tasks boring and irrelevant to military operations. However, this was not the case. Although no systematic motivational data were collected, subjects exhibited a number of behaviors which indicated that they were not bored by the computer tasks. Subjects who were performing poorly during the computer tasks frequently uttered statements of irritation and disgust. Moreover, after the test was over, subjects were extremely interested in determining how well they had done compared to the rest of the test group. Even though subjects received no material awards for their performance, they appeared to want to do well on the Phase I and Phase II tasks.

Some Suggestions for Further Research

In this pilot study, we developed a computer simulation which allows us:

a. To vary the density of a simulated minefield in order to present subjects with different levels of objective threat accurately.

b. To assess how subjects perceive the magnitude of objective threat, and;

c. To determine the relationship between perception of threat (i.e., minefield density) and simulated tactical decisions.

The minefield simulation was chosen for this pilot study because of its simplicity. Available computer graphic facilities permit the development of more complex one-sided and two-sided combat simulations. We could, for instance, have a two-sided game in which one subject controls a tank image and another subject controls a simulated TOW system. The tanker would have the capability of firing at the TOW, and the TOW operator could engage the tank. Measurements could be made of the tanker's and TOW operator's engagement behaviors. Other scenarios might involve tank battles and artillery and mortar fire.

Examination of the decision making aspects of suppression requires placing subjects under different degrees of risk, then examining and comparing their performance. The term risk implies something unwanted or to be avoided. Three broad categories of risk can be distinguished: loss of material benefits, loss of self-esteem, and loss of physical well-being. The proposed research will focus on the relationships between performance on combat simulations and the first two categories of risks. No attempt will be made to examine the effects of physical risk on performance.

Two types of experimentation might be conducted. In the first type, we would examine the influence of extrinsic material risks on simulation performance. Moreover, the proposed research could be designed to examine individual and group reactions to risky situations. Specifically, subjects could, in the individual consequences condition, be told that they will have to trade the points that they have earned for various types of positive and negative rewards. Thus, a soldier who has made a number of "wise" decisions, during Phase II, may be able to barter his points for a weekend pass, a small sum of money, or a few days of relaxed duty. On the other hand, a soldier who has accrued a negative score may be restricted to a few areas on post, may not receive any money, or may have to participate in extra duty. A similar situation will exist in the group consequences condition with the exception that points will count toward group rather than individual rewards. In the group condition, if one does well all participants may be given a weekend pass; if one does poorly, then everyone may be restricted to the barracks.

The second type of experimentation would examine the relationship between intrinsic motivation and simulation performance. In this research, a method similar to that previously described in the discussion section would be used; however, subjects would not receive any material rewards or punishments. Subjects would be selected on the basis of their "need for achievement" (intrinsic motivation). A highly motivated subject's performance on the simulation could be compared with a relatively unmotivated subject's performance.

The introduction of extrinsic and intrinsic risks and the introduction of the examination of performance under individual and "group-relevant" conditions are critical aspects of the proposed research (16). Prior research involving suppression experiments (7,8.9) have failed to include

risk as an independent variable. Research involving significant risks for both individuals and combat units could yield valuable information about the decision making processes of combat personnel and provide human factors data on decision making under risk which can be used to improve future models of fire suppression.

CONCLUSIONS

1. The computer paradigm used in this experiment appears to be a valid and useful tool to measure decision making for a no risk simulated combat scenario.

2. Subjects' mean estimates of mission success probability were close to actual probability of success.

3. Accuracy in estimating probability of success in Phase I was a fair predictor of decision making ability in Phase II.

4. As a group, subjects took chances more often during Phase II than they should have based on their own Phase I estimates of probabilities of success.

5. Neither the sex of subject nor sex of experimenter had a significant effect on subjects' accuracy in estimating probabilities or making tactical decisions, but females took longer to make tactical decisions than males.

RECOMMENDATION

Additional studies should be conducted to quantify the effect of risk on tactical decision making. These studies should be conducted using modifications of the computer simulation developed for this experiment.

REFERENCES

1. Corona, B.M., Jones, R.D., Randall, R.B., & Woodward, A.A. HFE load bearing system (LBS) test (HELLBST). Unpublished memorandum, US Army Human Engineering Laboratory, Aberdeen Proving Ground, MD, 9 Aug 1979.

2. Deci, E.L. The effects of contingent and non-contingent rewards and controls on intrinsic motivation. Organization Behavior and Human Performance, 1972, 8, 217-229.

3. Ebbesen, E.B., Parker, S., & Konechi, V.J. Laboratory and field analyses of decisions involving risk. Journal of Experimental Psychology: Human Perception and Performance, 1977, 3, 576-589.

4. Einhorn, H.J., & Hogarth, R.M. Confidence in judgment: Persistence of the illusion of validity. Psychological Review, 1978, 85, 395-416.

5. Hare, A.P. Handbook of small group research. New York: The Free Press, 1976.

6. Kogan, N., & Wallach, M.A. Risk taking: A study in cognition and personality. New York: Holt, Rinehart, & Winston, 1964.

7. Kogan, N., & Wallach, M.A. Risk taking as a function of the situation, the person, and the group. In New Directions in Psychology III. New York: Holt, Rinehart, and Winston, 1967.

8. Kruglanski, A.W., Friedman, I., & Zeevi, B. The effects of extrinsic incentive on some qualitative aspects of task performance. Journal of Personality and Social Psychology, 1971, 39, 606-617.

9. Morrison, D.F. Multivariate statistical methods. New York: McGraw-Hill, 1976.

10. Nieuwboer, H.W., & Tratensek, M. Field experiments as simulations. The CDEC Suppression Program. Proceedings of the 14th Annual US Army Operations Research Symposium, Vol II, Ft. Lee, VA, November 1975.

11. Report of the Army Scientific Advisory Panel Ad Hoc Group on Fire Suppression. Washington, DC, Department of the Army Office of the Deputy Chief, July 1975.

12. Slovic, P., Fischhoff, B., & Lichtenstein, S. Behavioral decision theory. Annual Review of Psychology, 1977, 28, 1-39.

13. Slovic, P., Weinstein, M., & Lichtenstein, S. Sex differences in the risks a person selects for himself and the risk he selects for someone else. Oregon Research Institute Research Bulletin, October 1967.

14. Small Arms Suppression Evaluation - Phase II. Headquarters, US Army Combat Developments Experimentation Command, Ft. Ord, CA, August 1976.

15. Torre, J.P., Jr. Suppression. Unpublished memorandum, US Army Human Engineering Laboratory, Aberdeen Proving Ground, MD, 28 June 1977.

16. Zander, A. The study of group behavior during four decades. The Journal of Applied Behavioral Science, 1979, 15, 272-282.

APPENDIX

EXPERIMENTAL INSTRUCTIONS

PART I

Since I want to make sure that everyone hears exactly the same directions, I will be reading a set of instructions to you. If you have any questions, please feel free to stop me. Is that clear?

During today's two sessions, you will be working on a project which is designed to find out how people make decisions about the chances that different events will be successful.

In the first part of the study, we want to see how well soldiers can estimate the chance that a target can move across the computer screen in front of you without hitting any of the small points of light. This test may indicate how well you can make difficult decisions with only small amounts of information.

Let me show you what I mean. Here you see a pattern of points and in the lower right hand corner, a small rectangular target that looks something like a tank. We want you to estimate the chance that the target will be able to cross between the bottom line on the screen and the top line without touching any of the points. You might consider this task similar to that faced by tank commanders trying to decide whether they should cross an area filled with artillery launched mines. You will make this estimate by pressing a number between 0% and 100% on this top row of keys. For example, if you feel that the target has no chance of crossing between the lines, you would press 0. If you feel that it has a 50% chance, you would press 50. And if you feel that it has a 100% chance of crossing, you would press 100.

After you make your estimate, you will press the "G" or go key, and the target will begin to move across the screen, like this. The target will always travel in a straight line and may start from any point below the bottom line on the screen. Keep in mind, that the target will not be visible until you press the "G" key. If the target hits a point or makes it across successfully, the trial will end and a new pattern of points will be displayed. You will repeat this procedure 100 times. Make your estimates of success quickly and carefully on the basis of the particular pattern that you see on the screen and the results of trials with similar patterns. Do you have any questions?

The number that you choose is always displayed in the box at the bottom of the screen. If you make a mistake, you can press the "C" or clear key and erase the number in the box. Then press the number that you want. If the box starts to flash on and off after you press "G" key, then you have used a number that is not allowed, such as 200. If this happens, press the "C" key, choose a number between 1 and 100, and press the "G" key again. The computer will signal you when the test is completed. Do you have any final questions?

Now let's try a few practice trials before the test begins. What do you think the chances are of the target getting through this pattern? Since there are only a few points, you might decide that there is a 90% chance of success. So you would push a 9 and a 0; and then push the "G" key.

Here is a second pattern; there are a few more points, so you might think that the chances are less: Make your estimate and push the "G" key.

Now try a few more practice trials and then we will begin the main test.

PART II

This is a second part of a Human Engineering Laboratory test of decision making. During the first part, you estimated the chance that a target would be able to cross an area on the computer screen without hitting any of the points of light. You had no control over the target's movements. During this part of the project, you will be able to decide whether or not to send the target across the screen. As before, the target always travels in a straight line and could begin from any point below or along the bottom line on the screen. If you decide to send the target across, you will push the "G" or go key. If you decide that it would be too risky to send the target out, you will push the "N" or no go key and a new pattern will be displayed.

Each time you make a decision, you will see three types of information in the display at the bottom of the screen. (E will point to the display). The trial number is displayed at the left. The score for each trial is displayed in the middle, and the score for all of the trials that you have completed is on the right. You can make two decisions: either to go or not to go; however, as you see on this diagram, four results are possible:

a. If you go and the target crosses the pattern successfully, you will earn 5 points.

b. If you go and the target is unsuccessful, you will lost 5 points.

c. If you don't go when you should have, you will lose 3 points.

d. If you don't go when you shouldn't have gone, you made a good decision and you will earn 1 point.

Your goal is to make as many successful crossings as possible; so it is more important to make it across than remain in one place. Examine the patterns carefully, and make the best decisions that you can. You will see 100 patterns. Each pattern is different. Do you have any questions about the procedure? This test will give us an indication of your decision-making ability, so do the best you can. The highest possible score on this test is 300 points.

Now let's try some practice trials before we begin the study.

Since there are only a few points in this pattern, you would probably decide that the target would cross successfully; so you would push the "G" key. Here's another pattern. Make your decision.

We'll try several more trials and then begin the actual trials. Do you have any questions about the procedure?